Schottky barriers and pn-junctions are the simplest active solid state devices. Their rectifying characteristics as well as the ability to expand or contract their space charge layer with bias is useful in many applications. With appropriate material and doping design, a wide variety of desirable operating characteristics can be obtained.

Schottky barriers are the simplest means to induce current rectification, and yet, it is most difficult to achieve this in a highly reproducible and predictable fashion for a variety of semiconductors. The reason, as explained in Sections 7.4 and 8.3, is their sensitivity to actual surfaces and their adsorbates that are often trapped between the metal and the semiconductor. The difficulties are reduced when this interfacial layer is expanded to at least a few monolayers of a desirable compound through which tunneling tends to stabilize the characteristics.

In this chapter, we will deal with a variety of empirical factors that help in fabricating Schottky barriers of desirable properties and stability.

In contrast, the pn-junction diode, while usually requiring a high-temperature diffusion treatment, is a device that can be understood more easily, and can be fabricated with more reproducibility. Its properties are sensitively related to the doping profile and can be designed to the extent that such a doping profile can be controlled. We will describe some examples and explain the relevant variations.

We finally identify a variety of applications of such devices and discuss their performance characteristics.
33.1 Schottky Barrier Devices

Schottky barriers were believed to be responsible for the rectifying characteristics of some of the early commercial semiconductor diodes, such as selenium* and cuprous oxide† rectifiers. However, their reproducible and rather stable behavior was derived from a thin pn-junction close to the actual metal contact and was created by the forming heat treatment during the industrial production process.

When intimate contacts are formed between the semiconductor and the metal, often yet unexplained changes in barrier height and variations with external parameters occur (e.g., changes with optical excitation in CdS—Stirn et al., 1973; Dussel et al., 1973).

The actual behavior of such Schottky barriers requires the discussion of certain specific devices which will be given below. A few general remarks, however, are in order first.

The selection of any electrode to a semiconductor is dictated by a number of conditions:

1. its workfunction;
2. the compatibility of the metal with the semiconductor:
   (a) avoiding of undesired chemical reactions;
   (b) avoiding of undesired diffusion into and doping of the semiconductor;
   (c) avoiding of ambient diffusion through the contact metal;
3. Surface wetting:
   (a) avoiding of droplet formation;
   (b) sufficient sticking of the metal layer to the surface (surviving the scotch-tape test, i.e., avoiding liftoff on the tape);
4. its ease of application;
5. convenient temperature for deposition;
6. good electrical and thermal behavior;
7. adaptability to integrated circuit fabrication technology.

* In selenium rectifiers, the “blocking” electrode is a tin-cadmium layer. During heat treatment, Cd diffuses into the adjacent Se, forming a layer of n-type CdSe and producing a heterojunction to the p-type Se (the other electrode was an Al or Fe layer with an ohmic behavior).
† The Cu₂O rectifier of Grondahl (1926) consists of a partially oxidized copper plate to which an ohmic contact of lead or graphite is attached. A pn-junction is probably formed within the oxidized layer close to the copper interface, as indicated by the sensitivity of the rectifying characteristic to small amounts of impurities in the copper before oxidation (Henisch, 1957).